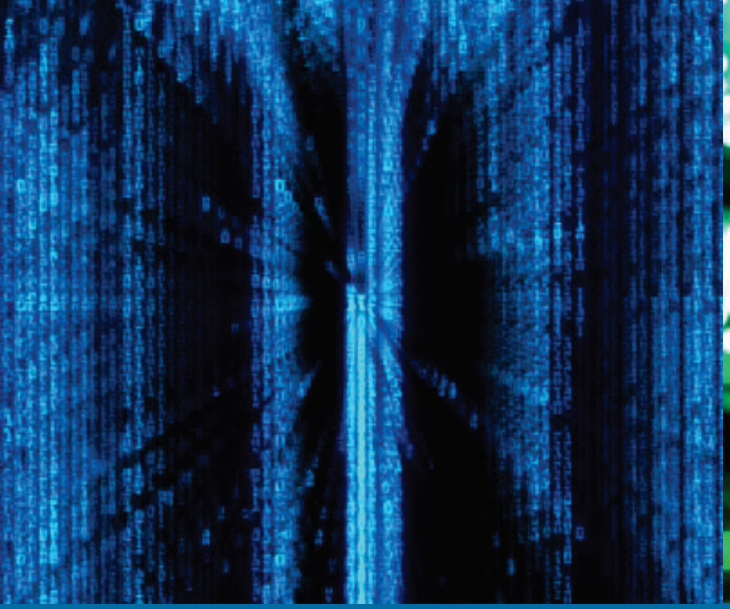

Shaping the Technology Roadmap of Virtual Reality (VR) and Augmented Reality (AR): Challenges and Standardization Needs

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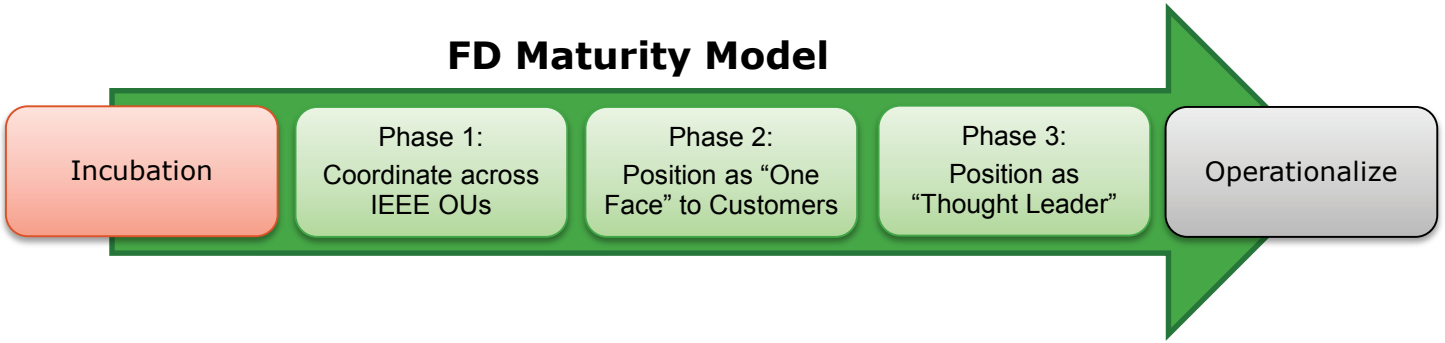
IEEE Future Directions Initiatives

IEEE Future Directions (FDC), a committee of the IEEE Technical Activities Board, identifies technologies as primary focus areas. The FDC initiates and then incubates IEEE wide initiatives involving all the IEEE operating units.



- Current Initiatives:
  - Big Data
  - CyberSecurity
  - Green ICT
  - Internet of Things
  - Software Defined Networks
  - Rebooting Computing
  - Smart Cities
  - Brain
  - **Digital Senses**
  - Smart Materials

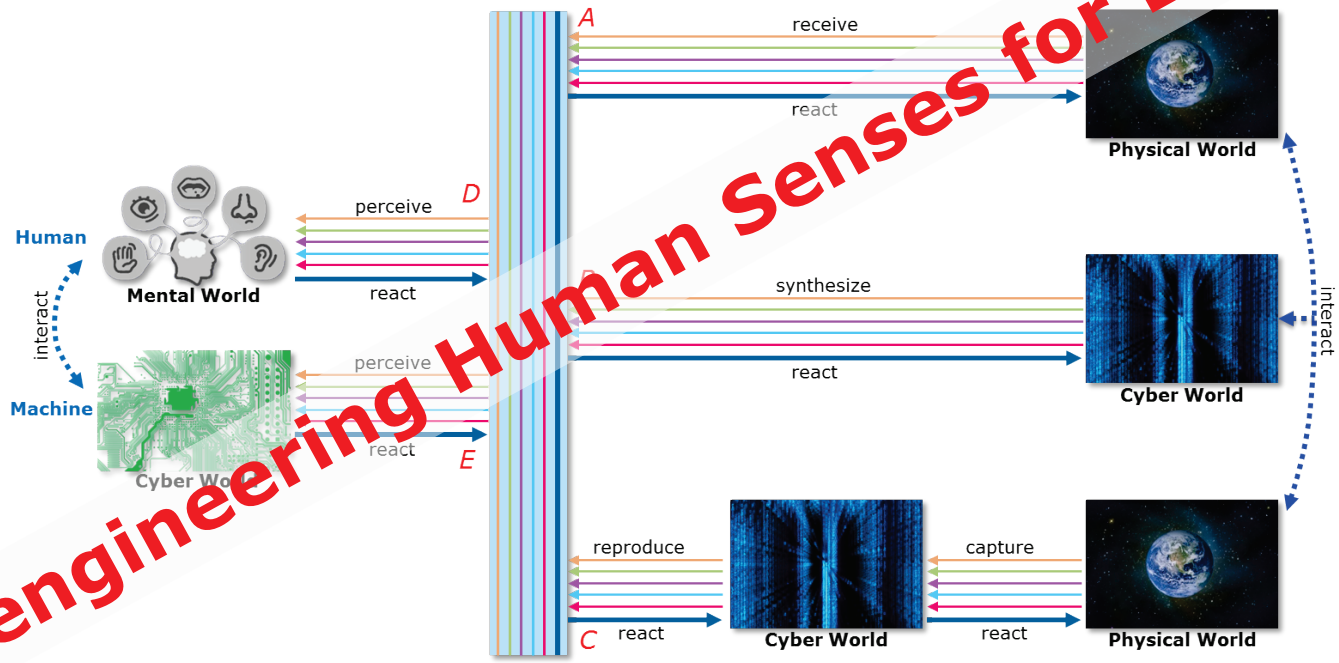
- Graduated Initiatives:
  - Cloud Computing
  - Life Sciences
  - Smart Grid
  - Transportation Electrification

IEEE Digital Senses Initiative
Member Societies

- **IEEE Consumer Electronics Society**
- **IEEE Engineering in Medicine and Biology Society**
- **IEEE Computer Society**
- **IEEE Communications Society**
- **IEEE Robotics and Automation Society**
- **IEEE Systems, Man, and Cybernetics Society**
- **IEEE Society on Social Implications of Technology**
- **IEEE Components, Packaging, and Manufacturing Technology Society**
- **IEEE Council on Electronic Design Automation**
- **IEEE Nanotechnology Council**
- **IEEE Sensors Council**
- **IEEE Council on RFID**
- **IEEE Standards Association**

IEEE Digital Senses Initiative
Scope

With a deeper understanding of how human senses work, we will be able to bring disruptive innovations into the areas of virtual reality, augmented reality, and human augmentation. IEEE Digital Senses Initiative is dedicated to advancing technologies that capture and reproduce, or synthesize the stimuli of various senses (sight, hearing, touch, smell, taste, etc.); combine the reproduced or synthesized stimuli with the naturally received stimuli in various ways; and help humans or enable machines to perceive, understand, and respond to the stimuli. Plans are underway to capture all the different perspectives via in-depth cross-disciplinary discussions, and to drive to a set of results which will facilitate disruptive innovations and foster cross-industry collaborations globally in three focus areas (virtual reality, augmented reality, human augmentation) and many other relevant areas (smart robots, wearables, computer healthcare, etc.).



Virtual Reality = (*B* and/or *C*) and *D*

Augmented/Mixed Reality = [*A* + (*B* and/or *C*)] and *D*

Reengineering Human Senses for Better Reality

IEEE Advancing Technology for Humanity

IEEE Digital Senses Initiative
Coverage Model

Transforming industries

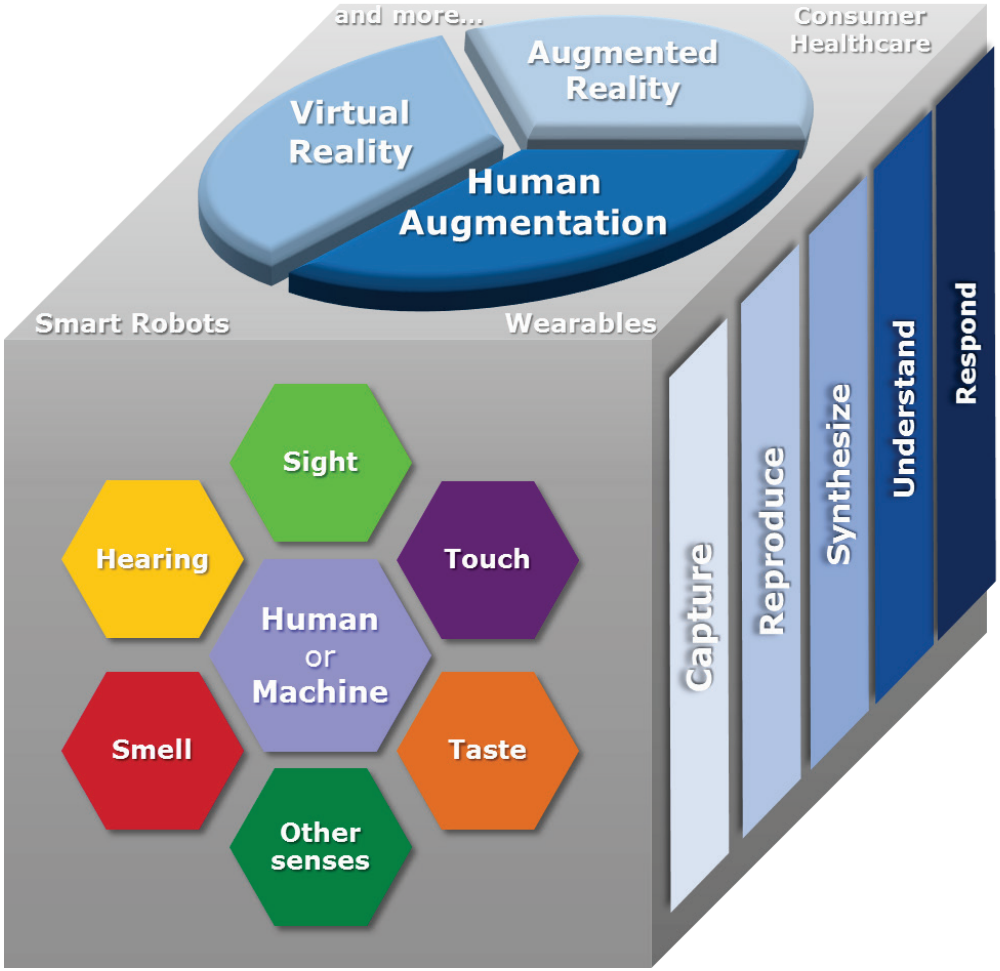
Privacy

Identity

Security

Trust

Ethics



Public awareness

User acceptance

Content richness

Ecosystem readiness

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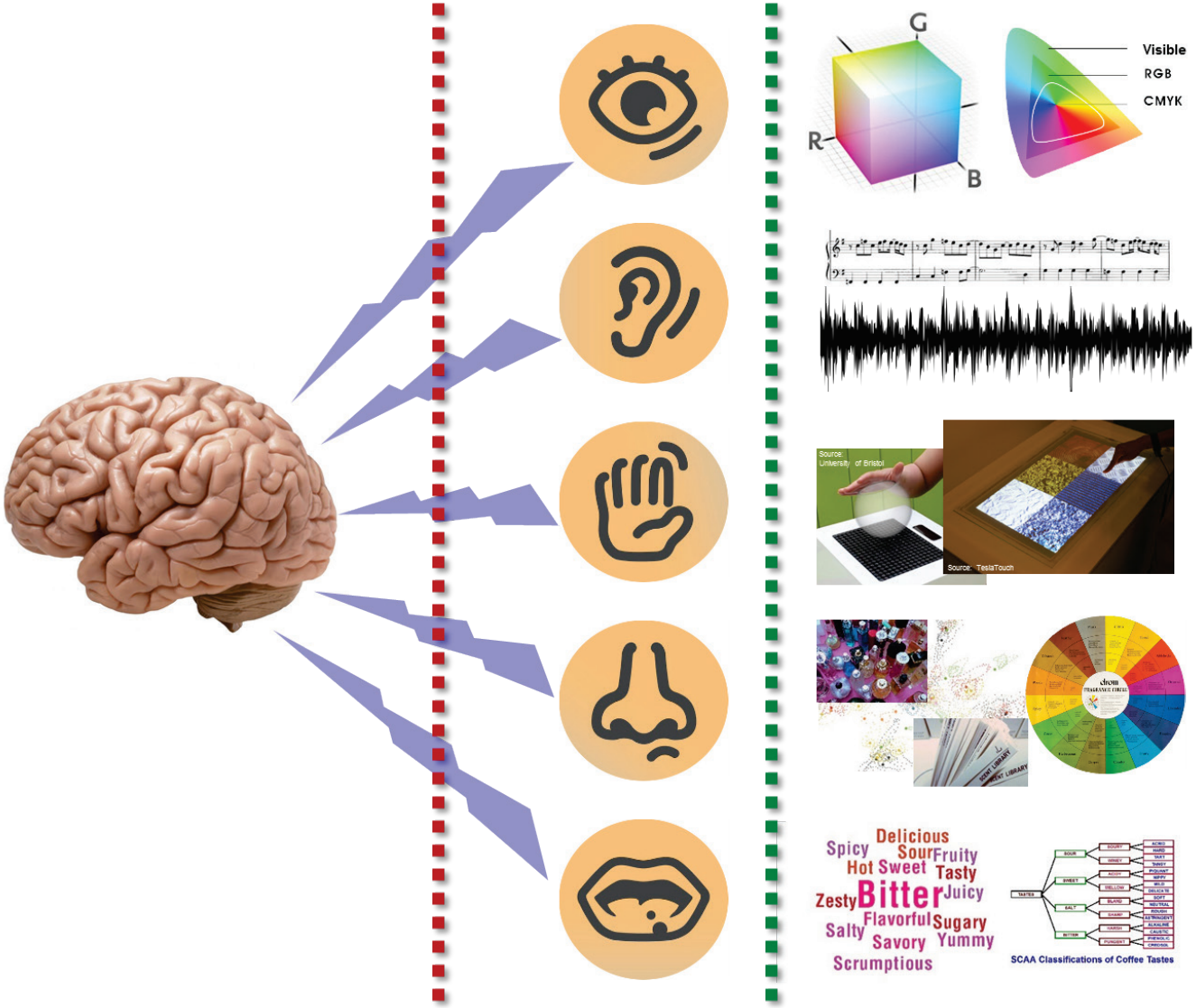
IEEE Digital Senses Initiative
Technology Map and Gap Analysis

	Sight	Hearing	Touch	Smell	Taste	Other senses
Capture	?	?	?	?	?	?
			?			
Reproduce	?	?	?	?	?	?
			?			
Synthesize	?	?	?	?	?	?
			?			
Understand	?	?	?	?	?	?
			?			
Respond	?	?	?	?	?	?
			?			

IEEE Digital Senses Initiative
Grand Challenges



IEEE Digital Senses Initiative
Master Plan

Operations

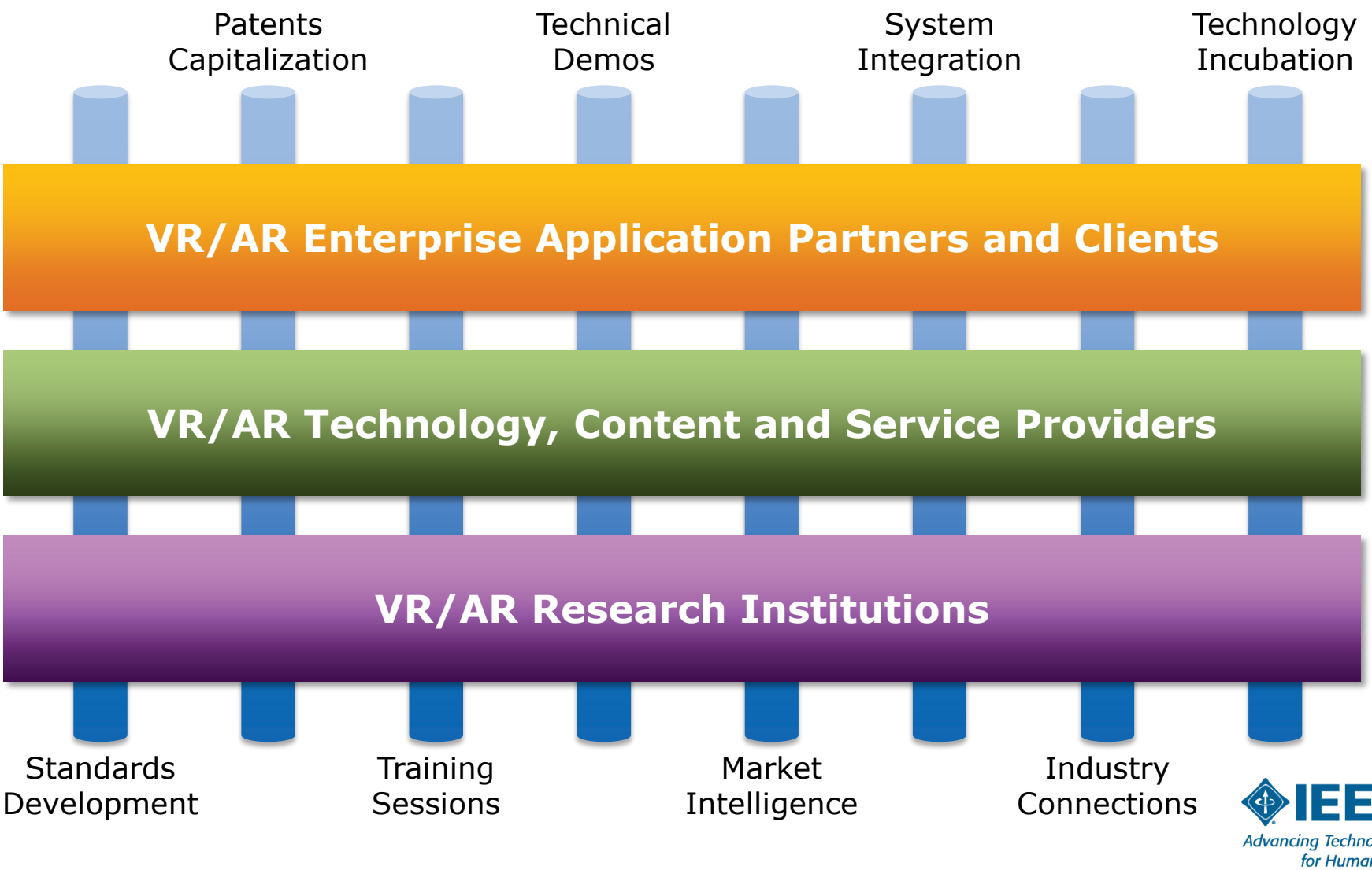
- ❑ Industry Collaborations
- ❑ Standards Activities
- ❑ Publicity and Communications
- ❑ Conferences and Exhibitions
- ❑ Membership Development
- ❑ Educational Activities
- ❑ Publications

IEEE Digital Senses Initiative
Master Plan

Operations

- ❑ **Industry Collaborations**
- ❑ Standards Activities
- ❑ Publicity and Communications
- ❑ Conferences and Exhibitions
- ❑ Membership Development
- ❑ Educational Activities
- ❑ Publications

IEEE Digital Senses Initiative
Centers of Excellence – Program Overview



IEEE DigitalSenses

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IEEE Digital Senses Initiative
Centers of Excellence – Sites Group 1

- The first two IEEE Digital Senses Centers of Excellence, which are intended to foster innovations in the areas of Virtual Reality, Augmented Reality and Human Augmentation in various ways, have been launched in Los Angeles and Shenzhen respectively.

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IEEE Digital Senses Initiative
Industry Applications

- We are proactively fostering and promoting the vertical applications of Virtual Reality, Augmented Reality and Human Augmentation in various industries.
  - VR/AR + Healthcare
  - VR/AR + Education
  - VR/AR + Retail
  - VR/AR + Home
  - VR/AR + Advertising
  - And more to come…

IEEE Digital Senses Initiative
Master Plan

IEEE DigitalSenses

Operations

- ❑ Industry Collaborations
- ❑ **Standards Activities**
- ❑ Publicity and Communications
- ❑ Conferences and Exhibitions
- ❑ Membership Development
- ❑ Educational Activities
- ❑ Publications

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IEEE Digital Senses Initiative
Standards Activities

- Standardization activities in DSI focus areas:
  - Harmonize existing standards
  - Identify standardization needs
  - Develop new standards to address gaps and white spaces
  - Provide reference implementations for selected standards
  - Facilitate global adoption of selected standards
- Expected outcomes in 2~5 years:
  - A series of globally adopted standards in DSI focus areas

- IEEE-SA provides a framework of solutions to support rapid introduction of new technologies to market

IEEE Digital Senses Initiative
Standards Activities *(cont.)*

- Standards Projects:
  - **IEEE P2048.1™** Standard for Virtual Reality and Augmented Reality: Device Taxonomy and Definitions
  - **IEEE P2048.2™** Standard for Virtual Reality and Augmented Reality: Immersive Video Taxonomy and Quality Metrics
  - **IEEE P2048.3™** Standard for Virtual Reality and Augmented Reality: Immersive Video File and Stream Formats
  - **IEEE P2048.4™** Standard for Virtual Reality and Augmented Reality: Person Identity
  - **IEEE P2048.5™** Standard for Virtual Reality and Augmented Reality: Environment Safety
  - **IEEE P2048.6™** Standard for Virtual Reality and Augmented Reality: Immersive User Interface
  - **IEEE P2048.7™** Standard for Virtual Reality and Augmented Reality: Map for Virtual Objects in the Real World
  - **IEEE P2048.8™** Standard for Virtual Reality and Augmented Reality: Interoperability between Virtual Objects and the Real World
  - **IEEE P2048.9™** Standard for Virtual Reality and Augmented Reality: Immersive Audio Taxonomy and Quality Metrics
  - **IEEE P2048.10™** Standard for Virtual Reality and Augmented Reality: Immersive Audio File and Stream Formats
  - **IEEE P2048.11™** Standard for Virtual Reality and Augmented Reality: In-Vehicle Augmented Reality
  - **IEEE P2048.12™** Standard for Virtual Reality and Augmented Reality: Content Ratings and Descriptors
  - **IEEE P3141™** Standard for 3D Body Processing

IEEE Digital Senses Initiative
Standards Activities *(cont.)*

- Pre-Standardization Efforts:
  - **IEEE IC15-004-01** 3D Body Processing
  - **IEEE IC15-002-02** Smart Glasses Roadmap
  - **IEEE IC16-004-02** Augmented Reality in the Oil/Gas/Electric Industry

IEEE VR/AR Working Group
Overview

- IEEE VR/AR Working Group is developing eight standards for virtual reality (VR) and augmented reality (AR). Having attracted participants from 200+ companies and institutions all over the world, the working group now is one of the largest forces dedicated to VR/AR standardization. The working group participants already include device manufacturers, content providers, service providers, technology developers, government agencies and other parties relevant to VR/AR, constituting an excellent mixture for the standards to be widely adopted.
- Technology is evolving very fast, especially in VR/AR. Our current being-developed standards only cover a small piece of the VR/AR landscape. We are actively collecting and identifying standardization needs. Some of them could become new projects in the coming months. We welcome interested stakeholders to join our efforts. We seek to provide unique value in the area of VR/AR, based on our depth and breadth of technical expertise. We also are interested in collaborating with other organizations.

IEEE VR/AR Working Group
Standards Projects

- IEEE P2048.1™ Standard for Virtual Reality and Augmented Reality: Device Taxonomy and Definitions
  - Scope:
    - This standard specifies the taxonomy and definitions for Virtual Reality (VR) and Augmented Reality (AR) devices.
  - Need for the Project:
    - Thanks to the recent technology advances and market growth, more and more companies are producing various VR/AR devices, which include but are not limited to head mounted displays, remote controllers, sensor stations, etc. This project is needed to reduce the emerging confusion in many VR/AR devices that have similar or misleading product names but significantly different functions or performance. By dividing VR/AR devices into different categories and levels, this standard could help end users choose the right devices, facilitate the development of cross-platform content and services, and promote a healthy growth of the VR/AR industry.

Standards Projects *(cont.)*

- IEEE P2048.2™ Standard for Virtual Reality and Augmented Reality: Immersive Video Taxonomy and Quality Metrics
  - Scope:
    - This standard specifies the taxonomy and quality metrics for immersive video.
  - Need for the Project:
    - Immersive video is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive video which are different in several aspects: 360 degrees or 180 degrees, stereoscopic or not, view point movable or not, focus adjustable or not, etc. This project is needed to reduce the confusion among these variants as they are often simply called "VR video" in today's market. By dividing immersive video into different categories and levels, this standard could help end users choose the right products, facilitate the development of cross-platform content and services, and promote a healthy growth of the VR industry.

Standards Projects *(cont.)*

- IEEE P2048.3™ Standard for Virtual Reality and Augmented Reality: Immersive Video File and Stream Formats
  - Scope:
    - This standard specifies the formats of immersive video files and streams, and the functions and interactions enabled by the formats.
  - Need for the Project:
    - Immersive video is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive video which are different in several aspects: 360 degrees or 180 degrees, stereoscopic or not, view point moveable or not, focus adjustable or not, etc. This project is needed to define the immersive video file and stream formats that support all the variants and facilitate the development of cross-platform content and services. This standard identifies existing applicable video coding standards, and defines the integration of these standards into immersive video.

Standards Projects *(cont.)*

- IEEE P2048.4™ Standard for Virtual Reality and Augmented Reality: Person Identity
  - Scope:
    - The standard specifies the requirements and methods for verifying a person's identity in virtual reality.
  - Need for the Project:
    - Many of the most important long-term applications for virtual reality, like distance education, e-commerce, work meetings, or simulation and training will rely on maintaining a meaningful representation of yourself that can travel across multiple servers. For example, you might be invited to a meeting at another company where you want to both appear as your chosen appearance (your 'avatar') and also be able to authenticate/prove that you are who you say you are. Similarly, you might want to go to school or go shopping as the same visual avatar. Given that VR will be a very 'social' medium, with many experiences depending on the presence of other people. The standard would allow a virtual reality user to; identify themselves to a site or service through a number of identity authorities; authenticate singular pieces of information without needing to trust the site with additional information; present themselves with specific visual assets; while having the visualization of their appearance certified.

IEEE VR/AR Working Group
Standards Projects *(cont.)*

- IEEE P2048.5™ Standard for Virtual Reality and Augmented Reality: Environment Safety
  - Scope:
    - This standard specifies recommendations for workstation and content consumption environment for Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and all related devices where a digital overlay might interact with the physical world, potentially impacting users' perception. This standard focuses on setting quality assurance and testing standards for qualifying products in said environments, achieving satisfactory safety levels for creation and consumption environment for all or majority of related products available for consumer and commercial purposes.
  - Need for the Project:
    - The rise of popularity of digital/analog reality products in consumer electronics, as well as in commercial / industrial fields is requiring a balance approach to designing a safe environment for developers and consumers. Virtual Reality and Augmented Reality enable new levels of productivity and speed up the training and content creation, yet standardization is necessary in order to provide a safe zone around the device and its operator. Standardization is viewed as the most efficient way to remove obstacles which operators or consumers might encounter, potentially including mandatory detection of objects in close proximity and releasing a warning if the interaction is deemed potentially hazardous. By providing necessary recommendations, we can reduce or eliminate potentially negative impacts which the industry faces.

Standards Projects *(cont.)*

- IEEE P2048.6™ Standard for Virtual Reality and Augmented Reality: Immersive User Interface
  - Scope:
    - This standard specifies the requirements and methods for enabling the immersive user interface in Virtual Reality (VR) applications, and the functions and interactions provided by the immersive user interface.
  - Need for the Project:
    - Most of the Virtual Reality (VR) applications are supposed to provide fully immersive experiences, which could be spoiled by non-immersive user interfaces such as the ones enabled by conventional keyboards, mice, and touchscreens. The industry has recognized the necessity of immersive user interfaces in VR applications, and has put lots of efforts in designing and developing various prototypes or component technologies. This project is needed to unite these efforts and specify the baselines of immersive user interfaces in order to help facilitate the development of cross-platform content and services, and promote a healthy growth of the VR industry.

Standards Projects *(cont.)*

- IEEE P2048.7™ Standard for Virtual Reality and Augmented Reality: Map for Virtual Objects in the Real World
  - Scope:
    - This standard specifies the requirements, systems, methods, testing and verification for Augmented Reality (AR) and Mixed Reality (MR) applications to create and use a map for virtual objects in the real world.
  - Need for the Project:
    - Augmented Reality (AR) and Mixed Reality (MR) applications add virtual objects on top of the real world. In many scenarios, virtual objects are supposed to be perceived as real objects so that they should have their own coordinates and orientations in the real world like real objects do. This project is needed to specify a unified map for various AR and MR applications to assign coordinates, orientations, and other arguments in the real world to virtual objects. The shared use of virtual objects among different users or even among different applications could be enabled by such a map.

Standards Projects *(cont.)*

- IEEE P2048.8™ Standard for Virtual Reality and Augmented Reality: Interoperability between Virtual Objects and the Real World
  - Scope:
    - This standard specifies the requirements, systems, methods, testing and verification for the interoperability between virtual objects and the real world in Augmented Reality (AR) and Mixed Reality (MR) applications.
  - Need for the Project:
    - Augmented Reality (AR) and Mixed Reality (MR) applications add virtual objects on top of the real world. In some scenarios, virtual objects are not only perceivable as real objects, but also supposed to interact with real objects and the real world. This project is needed to define different categories and levels of the interoperability between virtual objects and the real world, and specify the systems and methods that enable these categories and levels.

Standards Projects *(cont.)*

- IEEE P2048.9™ Standard for Virtual Reality and Augmented Reality: Immersive Audio Taxonomy and Quality Metrics
  - Scope:
    - This standard specifies the taxonomy and quality metrics for immersive audio.
  - Need for the Project:
    - Immersive audio is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive audio. This project is needed to reduce the confusion among these variants. By dividing immersive audio into different categories and levels, this standard will help end users choose the right products, facilitate the development of cross-platform content and services, and promote a healthy growth of the VR industry.

Standards Projects *(cont.)*

- IEEE P2048.10™ Standard for Virtual Reality and Augmented Reality: Immersive Audio File and Stream Formats
  - Scope:
    - This standard specifies the formats of immersive audio files and streams, and the functions and interactions enabled by the formats.
  - Need for the Project:
    - Immersive audio is an enabling technology behind many Virtual Reality (VR) applications in various vertical industries (e.g., media, entertainment, education, and tourism). Due to the rapid market growth recently, there have been many variants of immersive audio. This project is needed to define the immersive audio file and stream formats that support all the variants and facilitate the development of cross-platform content and services. This standard identifies existing applicable audio coding standards, and defines the integration of these standards into immersive audio.

Standards Projects *(cont.)*

- IEEE P2048.11™ Standard for Virtual Reality and Augmented Reality: In-Vehicle Augmented Reality
  - Scope:
    - This standard defines an overarching framework for Augmented Reality (AR) systems that assist drivers and/or passengers in vehicles.
  - Need for the Project:
    - In-vehicle augmented reality has become a new way of providing driving assistance and other infotainment services in vehicles, and is regarded as a promising vertical application of augmented reality. It can be implemented on various devices: Head Up Displays, Smart Glasses, etc. The common point is to make the user interface more friendly while avoiding or minimizing the risk of distracted driving. This project is needed to specify the requirements and methods for applying augmented reality in vehicles, identify existing applicable standards, and define the integration of these standards into a consistent vehicular environment.

Standards Projects *(cont.)*

- IEEE P2048.12™ Standard for Virtual Reality and Augmented Reality: Content Ratings and Descriptors
  - Scope:
    - This standard defines the content ratings and descriptors for Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR).
  - Need for the Project:
    - The immersive and realistic experiences enabled by Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) enrich people's lives, but some of them have the potential to cause mental or even physical problems (e.g. epileptic seizure). For example, unlike the situation in a theme park in the real world where people could choose not to ride a roller coaster after they see its performance and feel it is too dangerous, usually people are not fully aware of what they are facing before they put on a VR headset and enter a VR game for the first time. Even worse is the fact that people might not have the option to stop or escape when they are forced to ride a virtual roller coaster in a VR game. Hence, in addition to the traditional ratings and descriptors that address the ethical issues such as violence and sexual content, new ratings and descriptors are needed to protect people's health and safety from risky VR/AR/MR content. This project is needed to define a comprehensive set of ratings and descriptors for VR/AR/MR content. Existing applicable standards will be identified and leveraged.

Next Meetings

- The 2nd plenary meeting will be held in conjunction with the 8th AWE USA on June 2, 2017 at the Santa Clara Convention Center, 5001 Great America Pkwy, Santa Clara, CA, USA.
- The 3rd plenary meeting will be held in conjunction with the SIGGRAPH 2017 on August 2, 2017 at the Los Angeles Convention Center, 1201 S Figueroa St, Los Angeles, CA, USA.

IEEE Digital Senses Initiative
Standards Projects *(cont.)*

- IEEE P3141™ Standard for 3D Body Processing
  - Scope:
    - This standard addresses the fundamental attributes that contribute to 3D body processing quality of experiences, as well as identifying and analyzing existing metrics and other useful information relating to these attributes. It defines a standardized suite of objective and subjective methods, tools and frameworks for assessing 3D body processing quality of experience attributes, and it specifies methods, tools and frameworks to facilitate standards-based interoperability, communication, security and comparison among 3D body processing technologies such as 3D/depth sensors, scanners, digitization, simulation and modeling, analytics and animation/visualization for solution providers as well as for consumer facing companies such as in retail, health/wellness, sports/athletics, medical industries.
  - Need for the Project:
    - Market and technology fragmentation amongst 3D body processing technology providers is driving a lack of agreement around quality, interoperability, communication and security. As a result, industries such as retail, health/wellness, sports/athletics and medical are unable to deliver scalable quality of experiences. This project aims to address these challenges.

IEEE Digital Senses Initiative
Pre-Standardization Efforts

- IEEE IC15-004-01 3D Body Processing
  - The motivations and goals are to bring together an ecosystem of players to co-develop an assessment of standards needs and to propose new standard(s) around enabling 3D body processing which includes the capture, processing, storage, sharing and (augmented) representation "Of-the-body" and "On-the-body" technologies;
  - This exploration will include:
    - Identify and classify types of 3D body processing technologies;
    - Identify and classify use cases of 3D body processing;
    - Identify gaps in existing nascent standards and recommended practices as 3D body processing spreads beyond first adopters;
    - Identify need and propose PARs for new standards and best practices for 3D body processing and adjacent technologies (like 2D augmented reality).

Pre-Standardization Efforts *(cont.)*

- IEEE IC15-002-02 Smart Glasses Roadmap
  - Augmented Reality (and Virtual Reality) technologies are rapidly developing in both the industrial and consumer space, and public interest is growing as information about these technologies is increasingly appearing in mainstream media. Consumer and industrial adoption and acceptance will be dependent on the readiness of technologies relative to interoperability, user interface, cost effectiveness, application, as well as the foundational technology functionality required to provide a positive customer experience.
  - Smart Glasses is just one of the functional elements that enable these enhanced reality experiences, yet it is a priority issue as it is the "hands-on" element for users, thus the user experience with Smart Glasses will be a driver or a barrier for widespread adoption of these technologies.
  - This project aims to analyze the markets, use cases and technology considerations that must be addressed to accelerate enhanced reality technology readiness and adoption. It plans to engage with industry experts to identify commonalities and attributes already in place, and more importantly the needs and gaps that need to be addressed.
  - The focus of the effort will be to develop a roadmap of needs and actions for these technologies including technology standards needs that will enable interoperability and help to address user expectations.

IEEE Digital Senses Initiative
Pre-Standardization Efforts *(cont.)*

- IEEE IC16-004-02 Augmented Reality in the Oil/Gas/Electric Industry
  - IEEE hosted a workshop in October 2015, exploring the application of augmented reality (AR) solutions in the oil and gas industry. Coupled with interest within the electric power industry, workshop participants expressed an interest in forming an ongoing interest group to facilitate collaboration in identifying requirements, standards needs and other issues, to help enable AR solutions, as well as potentially mixed and virtual reality solutions, that can benefit these industries.
  - Existing augmented reality devices have not yet achieved a state of readiness for widespread application in the oil, gas, and electric industries. "Heads up Display" type devices are of particular interest, however a variety of issues need to be overcome including ruggedness, wireless connectivity, use case viability and human factors considerations.
  - While each of the represented industries have some industry-specific interests, there are sufficient commonalities such that aggregating efforts is anticipated to provide a beneficial approach to achieving efficient solutions. Both hardware and software issues can be largely influenced by standards.
  - Participants in this activity will identify existing standards, and standards in progress that are relevant and valuable to supporting AR in the electric/oil/gas industries, as well as identifying gaps where new standards efforts are recommended – analysis will include not only IEEE standards, but standards and specification available via other SDOs, alliances, etc. Use Cases will also be an area of work activity – development of a collection of use cases that are 1) of mutual interest across electric/oil/gas, 2) of segment specific interest. Prioritize use cases and identify applicable standards and gaps in existing standards.

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Contact us for participation and collaboration opportunities

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Email: y.yuan@ieee.org
LinkedIn: http://www.linkedin.com/in/DrYuYuan

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